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The Trauma Patient Simulator (TPS) is an interactive, multimedia, virtual-reality-based simulator that offers realistic, time-critical practice to the trauma-care provider. The system presents trauma incidents in a three-dimensional (3-D) visual and aural scenario. A 3-D virtual-human model with realistic visible injuries and internal trauma exhibits medical signs and symptoms with real-time, true-to-life physiological behavior. TPS databases contain casualty and scenario data, define patient assessment and care procedures, and provide rules for simulation and interaction. Cardiovascular, respiratory, and neurological variables are continuously updated in response to changing anatomical, physiological, and trauma-treatment status. The caregiver interacts with the casualty through anatomical "hot spots" (e.g., neck, left) related to protocol actions (e.g., check pulse), through spoken dialog with natural language processing that allows the user to speak to the patient and to hear his or her responses, and through context-sensitive menus. The TPS provides realistic and varied trauma-care experience prior to the challenge of a combat or other dangerous situation.

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Paul N. Kyahl 7/27/98
PI - Signature Date

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SYMBOLS AND ACRONYMS

3-D	Three dimensional
ABCDs	Airway, breathing, circulation, deformity/disability
AMEDD	Army Medical Department
AMSUS	Association of Military Surgeons of the United States
AdvSim	Advanced Simulation Corporation
AGP	Accelerated Graphics Port
ATLS	Advanced trauma life support
ATM	Advanced trauma management
CD	Compact disk
C&S	Center and School
COM	Component object model
COR	Contracting Officer's Representative
COTR	Contracting Officer's Technical Representative
COTS	Commercial off-the-shelf
DIS	Distributed interactive simulation
DLL	Dynamically linked library
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
HR	Heart rate
HTML	Hypertext markup language
I/ITSEC	Interservice/Industry Training, Simulation, and Education Conference
IV	Intravenous
LSTAT	Life support for trauma and transport
MAP	Mean arterial pressure
MB	Megabytes
MCCS	Medical command and control system
MHz	Megahertz
MOS	Military occupational specialty
MRMC	Medical Research and Materiel Command
MMVR	Medicine Meets Virtual Reality
NATO	North Atlantic Treaty Organization
NBC	Nuclear, biological, and chemical
NLP	Natural language processing
OLE	Object linking and embedding
PaO2	Partial pressure of arterial oxygen

PA	Physician Assistant
PAS	Patient Assessment Simulator
PC	Personal computer
RAM	Random access memory
RTI	Research Triangle Institute
SME	Subject matter expert
SV	Stroke volume
TES	Tactical engagement simulation
TPS	Trauma Patient Simulator
VMET	Virtual Medical Trainer
VR	Virtual reality
V&V	Verification and validation
WRAIR	Walter Reed Army Institute of Research

1.0 INTRODUCTION

1.1 Nature of the Problem

The overall goal of this project is to save lives and reduce morbidity through improved, interactive, and realistic training for battlefield medical personnel. Specifically, this project developed and demonstrated a Trauma Patient Simulator (TPS) for computer-based training in pre-hospital emergency care.

In modern warfare, approximately 90% of all combat deaths occur on the battlefield, forward of any type of medical aid station. About 44% of these casualties die of severe blood loss, and about 12% of combat deaths occur after the casualty has received some level of medical care. Of those receiving care, 25% die of shock (Bellamy, 1994). Combat medical personnel are trained to provide casualty care during these critical moments, yet they have limited opportunity for realistic training beforehand.

Current training that relies on printed media and moulaged-actors is limited in its range of combat injuries, scenarios, and the dynamic physiological consequences of trauma and treatment. Physiological modeling of the trauma patient can simulate the dynamic effects of trauma as well as responses to medical intervention. Virtual reality-based training can place the caregiver in a three-dimensional (3-D) scenario, providing observation from any angle and position, interaction and manipulation of the patient and medical devices, and immersion in a realistic visual and audible environment. Trauma patient simulation can therefore emphasize the critical element of time, as well as teach skills and procedures, for more realistic practice of combat casualty care.

1.2 Objective

The project objective is to provide a framework, an architecture, and a meaningful step towards equipping the Army medical community with a family of practical and affordable casualty simulator/trainers. To meet these objectives, the **specific aims** of the project are to:

(1) Develop a working Trauma Patient Simulator (TPS) consisting of models of (a) physiological systems and functions, (b) the physiological dynamic consequences of trauma on these systems, (c) the effects of medical intervention on these systems, and (d) the effects of interaction with anticipated military medical technology.

(2) Provide an accurate and engaging visible, audible, and behavioral trauma simulation environment for practicing emergency trauma care.

(3) Develop a scaleable system architecture that is suitable for individual/home use, team learning use, distant learning use, and fully immersive use in advanced learning environments such as 21st-century classrooms.

(4) Deliver a simulator architecture that is compatible with constructive tactical engagement simulations (TES) and evolving mission planning and rehearsal training systems.

(5) Demonstrate a representative set of combat casualty scenarios, trauma casualty cases, and trauma patient care simulations in conjunction with a constructive Tactical Engagement Simulation.

2.0 METHODS

2.1 Define trauma simulation requirements and identify available resources

The traditional approach to systems development begins with a comprehensive requirements analysis that results in a complete system specification for the developers. Because TPS was a demonstration project and not a product development, a Rapid Prototype Development approach was employed. Rapid Prototype Development acknowledges the process of change, especially whenever the system employs rapidly-changing state-of-the-art technologies. The requirements analysis and design documents are more goal driven, with interim guidelines, and specifications are subjected to reassessment and revision over the course of the project.

Teleconferences, video teleconferences, and meetings with representatives from AMEDD C&S and MRMC were held to review RTI's prior work on the Virtual Medical Trainer (VMET) for patient assessment training, to determine TPS system requirements, to identify Subject Matter Experts (SMEs), and to identify available data and library resources. The proposed technical approach, content, and deliverables, current work in progress, user expectations, and system requirements were discussed. The resulting commentary was assimilated into an informal requirements document that was used to guide VMET-TPS development.

A notable outcome of this process was dropping the specific aim to deliver a simulator architecture that is compatible with constructive tactical engagement simulations (TES) and evolving mission planning and rehearsal training systems. Rather, the effort was focused on the simulator proper.

2.2 Develop physiological models to interactively simulate the dynamic effects of trauma, chemical agents, emergency care, and pharmacological interventions.

The physiological engine in VMET-TPS is an adaptation of BODY Simulation® (hereinafter: BODY), an anesthesiology training system produced by Advanced Simulation Corporation (Point Roberts, WA), N. Ty Smith, M. D, and Terence M. Davidson, M.D, (San Diego, CA). Advanced Simulation Corporation (AdvSim), under subcontract to RTI, revised and extended the BODY software to meet new requirements for trauma patient simulation. Since BODY was an existing product based on published models, the physiological models within BODY were assumed *a priori* to be accurate and a suitable foundation for trauma simulation.

BODY is based on **multiple modeling** and **transport modeling**. Multiple modeling allows multiple complex models, each of which can stand by itself or be combined to interact in complex ways. The transport model allows transport of anything normally carried by the blood, pulmonary gases, or nerve fibers, such as gases, vapors, drugs, hormones, pH, heat, and information. The multiple-compartment transport architecture represents physiological functions and pharmacological actions and interactions. The physiology model, as does the real body, centers around a cardiovascular model, which consists of a beating heart; blood to transport gases, ions, chemicals, drugs, etc.; and compartments, such as the brain, heart, and liver. The pulsatile function of the heart, although computationally very intensive, provides outputs (blood pressures and flows) that resemble the real cardiovascular system, and add immeasurably to the realism of the simulation.

BODY is a 45-compartment multiple transport model of the lungs, heart, and circulation. Within each compartment is a set of "receptor compartments", each for a different agent. Each receptor compartment contains a concentration-effect relationship, e.g., cardiac contractility versus concentration of norepinephrine. With few exceptions, the concentration-effect relationships are implemented as sigmoid curves.

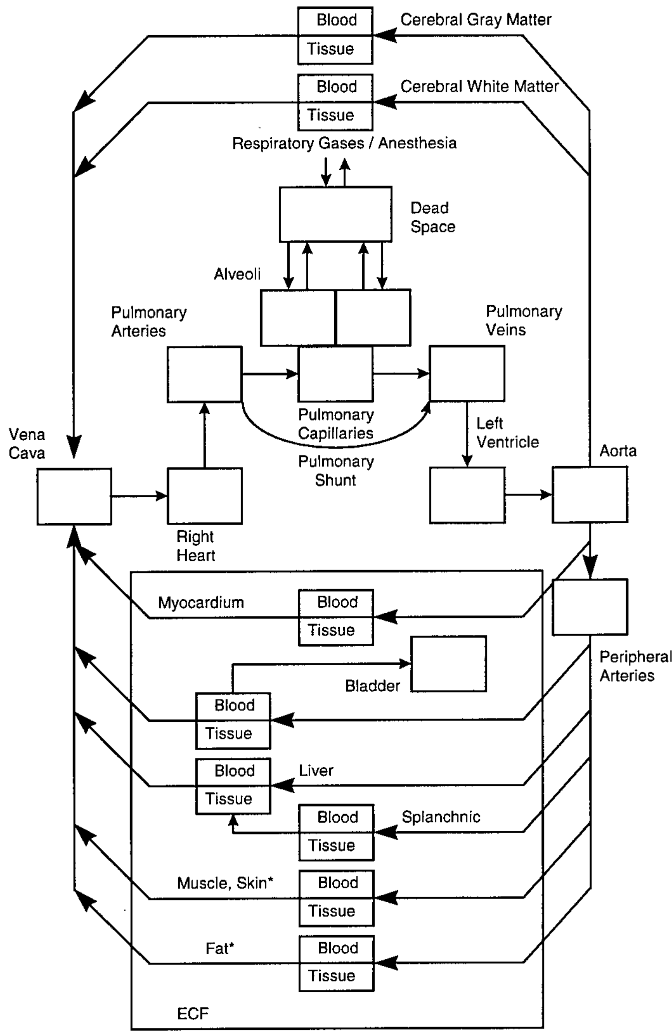

Figure 1. The AdvSim BODY simulation model.

Because BODY is a transport model, it can convey materials in the lungs and blood into and out of the various compartments. In particular, it can transport information, ions (including pH), dissolved or bound gases, inhaled agents (anesthetics or toxins), drugs, and chemical agents via any route (intravenous, intramuscular, transcutaneous, subcutaneous, and lungs), hormones, dyes, tracers, and markers.

BODY also has clinically-oriented features that enhance the simulation. Critical incidents that are currently implemented for anesthesiology simulation include bleeding, pain, esophageal intubation, airway obstruction, right mainstem bronchus intubation, difficult intubations, ventilator failure, oxygen-supply pressure loss, soda lime depletion, and bigeminy or trigeminy cardiac rhythms.

2.3 Develop visual, aural, and behavioral trauma casualty models

Casualty simulation comprises the virtual representation of the trauma patient, a representation of physiological status, and means for effecting changes in the virtual patient and physiological status. To provide an accurate and engaging simulation, we developed a set of cooperative models working within a multi-tasking software environment that simulates (a) the visual and aural properties of combat casualties; (b) the visual, aural, and physical combat environment; (c) the dialog between caregiver and patient during patient assessment; (d) the interactive provision of emergency medical care; and (e) provider and patient interaction with medical materiel.

We identified representative examples of the human body, clothing, wounds, medical and military materiel, and combat environment characteristics. For medical and military materiel, the COTR and SMEs helped determine an appropriate set of graphic objects for both medical care

and scenario representation. Wound graphics provided by the program sponsor were catalogued in a relational database and used to create artwork for applying similar wounds to the virtual casualties. RTI then developed dynamic visual models to meet the trauma simulator specifications. Visual models were developed, edited, and processed using 3D Studio, 3D Studio Max, and Character Studio (Kinetix division of Autodesk, San Francisco, CA), 4D Paint (4DVision, Denver, CO), and DirectX 3D Converter (Microsoft, Redmond, WA).

A representative set of audio samples was acquired or recorded for presentation of body, speech, and environmental sounds. In addition, a text-to-speech software module was acquired for more flexible computer-generated speech. Although these data were of limited quantity, the audio samples were sufficient for audio software development. The software plays continuous and segmented audio wave files, manages text-to-speech output, and mixes multiple audio sources as necessary for realistic scenario and trauma-care simulation.

The patient/caregiver dialogs (i.e., during patient assessment) comprise a set of caregiver questions, caregiver statements, and expected patient responses. COTS software (IBM ViaVoice) acquires and analyzes speech, and the recognized word list is submitted for natural language processing (NLP) to match the spoken phrase with the expected caregiver question. Using NLP, an appropriate casualty response (related to the patient's level of consciousness) is identified in the speech/response data base and the patient's response is presented as a prerecorded audio file (from a speech actor), synthesized speech from the text-to-speech module, or as an on-screen text message.

2.4 Develop software simulation environment

The simulation environment comprises simulation management, casualty simulation, and care provision. The **simulation management** process coordinates all modeling, simulation, presentation, and user interaction for generating and executing casualty care simulations. The **casualty simulation** processes include all casualty-specific modeling and simulation functions described in Sections 2.2 and 2.3. These casualty simulations run autonomously (as in real life) as the patient's post-trauma medical condition changes and medical care is provided. The **care provision** comprises casualty information presentation, casualty-caregiver dialog, and medical procedures.

For software development, both the primary software environment and VR graphics support software were considered. For VR graphics rendering, Windows 95 supports DirectX 3D version 4.0, while Windows NT 4.0 supports both DirectX 3D version 3.0 and OpenGL. Because DirectX 3D version 4.0 offers a better graphics-performance/hardware-cost ratio, we selected Microsoft Windows 95 as the primary software environment

The TPS uses Microsoft's DirectX3-D video and DirectX audio drivers for virtual environment support. The simulation management and user interface were coded in Microsoft Visual Basic 5.0, the virtual reality environment, BODY, and NLP were coded in Microsoft Visual C++ , and the database support was coded in Microsoft Access 97 Basic. COTS software libraries and ActiveX controls (i.e., add-ons to Microsoft Visual Basic and C++) were used as available to provide needed software functions and enhanced capabilities. Extensive use of object-oriented

data structures and program code enhanced modularity and ease of intermodule communication via the Microsoft Component Object Model (COM) architecture.

2.5 Identify, develop, and integrate hardware and software components

To meet the specific aim that the TPS would be suitable for individual/home use, the underlying system hardware must be affordable and execute within a standard software environment. By recognizing that computer hardware costs generally diminish about 25% per annum for a given level of computer performance, we identified commercially available personal computer systems in the $4000 price range. We reasoned that by the time the TPS would be ready for market (say 2 years), the required computer should cost less than $2500. By the end of the project, this cost goal for the hardware platform had been met.

Our prior VMET patient assessment simulator (PAS) was developed on a 200 MHz Pentium Pro platform and installed on 166 MHz Pentium machines with 3-D graphics and 128 MB RAM. These systems proved barely adequate for maneuvering in the 3-D patient assessment window. Based on this experience and the additional computational requirements of the physiological engine, the TPS demonstration systems were specified as: 300 MHz computer Pentium II, 128 MB RAM, 1.2 GB hard disk or larger, 3-D AGP graphics processor with 8 MB video RAM, Iomega ZIP drive, CD drive, and dual sound subsystems (audio output and speech input).

Given the system budget, computer systems available from established computer manufacturers were considered as the TPS demonstration platform. Since two systems would be delivered to the Army, it was deemed important that on-site or rapid-turnaround warranty service be available from the manufacturer. A dual-processor Pentium II platform with one processor installed from Tri-Star Computers was selected, to allow future performance enhancement under NT 5.0.

2.6 Deliver, install, and demonstrate the trauma patient simulator

To help assure development of a useful training tool, work-in-progress was demonstrated to the COR, COTR, their representatives, and subject matter experts (SMEs) throughout the project. To obtain a wide spectrum of feedback from the medical community at large, the TPS was also demonstrated at a number of military and civilian scientific symposia and trade shows.

The Army Institute for Surgical Research at Brooke Army Medical Center was selected for delivery, installation, and final demonstration of the prototype system. After a period of review and familiarization, the TPS is expected to be transferred to the AMEDD C&S for evaluation as a training tool in the physician assistant (PA) program.

3.0 RESULTS

The results of this work can be viewed at two levels. The global level is represented by the prototype integrated VMET-TPS system for training in trauma-patient care. The lower level comprises the VMET architecture which employs various sets of software and data libraries to render casualty scenes, simulate physiological functions, govern what medical care may be provided, and model casualty-caregiver dialogs.

Because the library and database content may be readily modified and expanded, the integrated VMET-TPS system is not limited to the delivered demonstration sets of trauma case scenarios and medical care procedures.

The following sections describe the system overview and discuss examples of key subsystems, libraries, and data sets. The section concludes with a summary of the user interface and the results of various demonstrations.

3.1 System overview and architecture

3.1.1 Overview

VMET-TPS is an interactive, multimedia, virtual-reality-based simulator that offers realistic practice to the trauma-care provider. The system presents the user with a 3-D visual and aural scenario in which a trauma incident has occurred. Mechanisms-of-injury currently represented include falls, gunshot wounds, vehicle collisions, explosions, and blunt injury. The user may freely navigate within the scene and view the scene and patient from any position and angle.

The trauma patient is a 3-D virtual model with realistic visible injuries and internal trauma that exhibit medical signs and symptoms with real-time, true-to-life physiological behavior. Physiological information gives the user insight into the events that follow treatment or failure to take appropriate action. Caregiver/patient dialog that incorporates NLP allows the user to speak to the patient and to hear his or her responses.

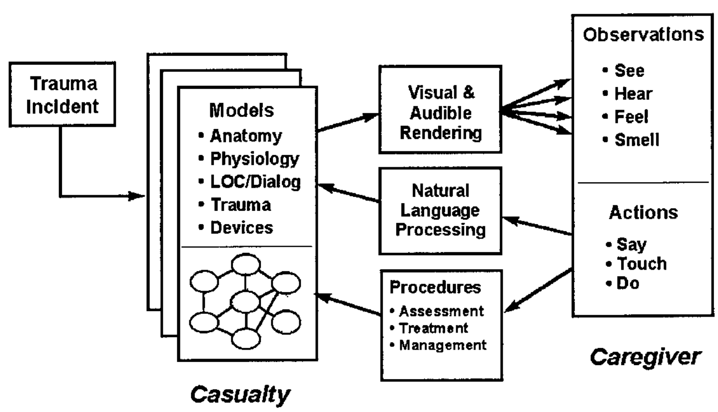

Figure 2. Conceptual model of trauma care.

The caregiver has available all aspects of trauma-patient assessment and a selected set of medical procedures. Beginning with entering and sizing up the scene, the caregiver can determine level of consciousness, check the ABCDs, and attend to major life-threatening conditions. Unexpected calamities, such as hemorrhage, emboli, airway obstruction, or myocardial infarction can be programmed to happen at random and thus provide a rich set of medical challenges.

VMET-TPS records all user interactions for post-session review, along with the pertinent physiological data. Developed for free-play simulation and student-performance examinations,

VMET-TPS can also be used for introductory instruction with built-in guidance from standard protocols in trauma life support. A flexible, database-driven structure supports multiple levels of caregiver expertise and alternative treatment protocols.

3.1.2 Architecture

In VMET-PAS, the initial member of the virtual medical trainer family, special attention was given to creating a flexible and modular framework. Although limited to patient assessment, VMET-PAS made extensive use of databases to hold casualty and scenario data, to define the set of diagnostic methods available to the caregiver, and to provide rules of interaction related to the scene, casualty, medical procedures, and resources (Kizakevich, et al, 1997). This architecture was retained as a starting point for TPS development.

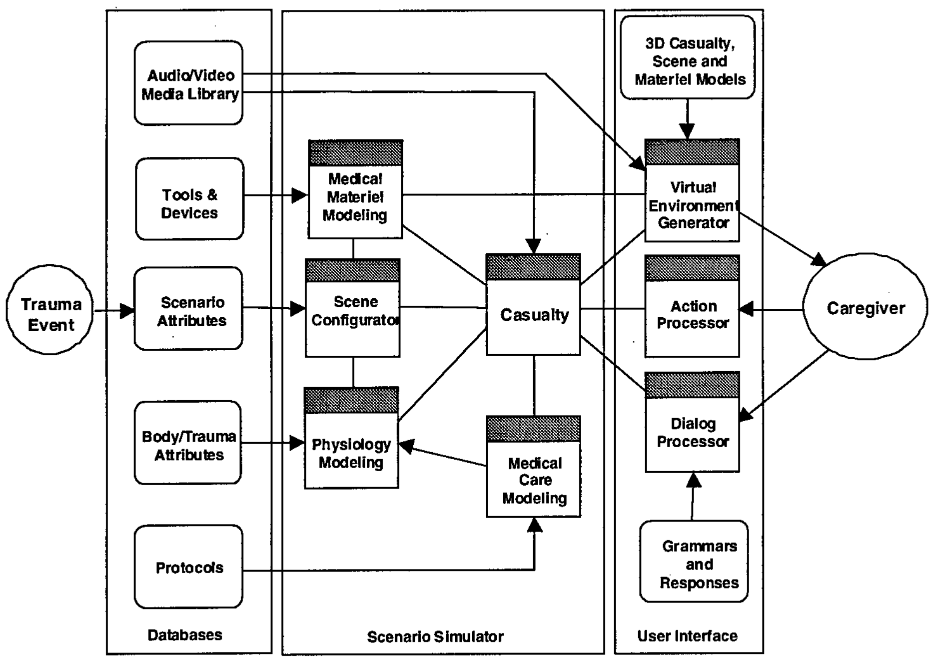

Figure 3. Top-level functional diagram of the TPS system architecture.

VMET-TPS comprises three primary components: databases, a scenario simulator, and a user interface (Figure 3). The databases can be modified to accommodate changes in procedures, new medical devices and equipment, and new visual and physiological representations of patients and their wounds. Each database provides information to the scenario simulator, a set of programs that creates the virtual casualty and its setting, and operates on intervention information to produce responses for the user. The user interface processes and logs navigation and procedural choices made by the caregiver and controls the presentation of the virtual casualty.

The following databases define, organize, relate, and configure scenarios, casualties, and procedural aspects of trauma casualty simulation:

Audio/Video: images, movies, sounds and speech available for TPS simulations.

3-D Casualty/Scene/Material: three-dimensional models of uninjured and injured body parts, scenes, medical devices, and other objects. Defines parent-child relationships among objects for correlated user interaction and graphics visualization.

Tools/Devices: defines how tools are accessed in the user interface and applied in the scene.

Scenario: attributes of various scenarios including scenes, scene disturbances, environmental conditions, injured persons, sounds, and events.

Body/Trauma: attributes of persons, body parts, injuries, and organs. Extensive body object attributes that are set to define particular injuries, their visual representation, related multimedia files, appropriate medical treatment, and post-treatment visualization.

Protocols: a hierarchy of protocols, tasks, and actions that comprise patient assessment and trauma care. Defines relationships among body objects, medical devices, assessment tools, and the user interface.

Grammars/Responses: caregiver statements, patient responses, and language rules for caregiver-patient dialog.

Administrative: administration records including instructor and student registration, student-casualty interaction logs, physiological data logs, and other scoring information.

Software modularity allows functional components to be replaced without major redesign of the system. For example, each database, the 3-D model, and the physiological engine are complete entities with defined interfaces to the simulator/trainer. As 3-D graphics capabilities improve, the virtual body can be upgraded in appearance and complexity without altering other parts of the system. Similarly, as physiological models become more accurate and accommodate a wider range of capabilities (e.g., responses to more drugs, drug interactions, hypothermia), the physiological engine may be replaced, and the change will be transparent to the user. For larger, multi-casualty or multi-caregiver simulations, the component architecture can facilitate the distribution of computational workload across several computers.

3.2 Physiological modeling

The physiological model comprises two layers, the VMET-TPS simulation executive-model and AdvSim's BODY model. The VMET-TPS executive-model provides overall control of the simulation based on a one-second timing interval. The executive-model reads the VMET-TPS database to initialize simulation parameters, interprets the critical-incidents script, provides supervisory control over BODY's simulation program, and stores physiological data for subsequent review and scoring. The executive-model also analyzes BODY's simulation data to determine various body states (e.g., level of consciousness), modifies BODY's parameters according to patient-care events, and coordinates time-dependent activities among various software subsystems (e.g., bag-squeeze visual representation and BODY's ventilation volume). This design isolates the BODY model as an autonomous component, permitting independent development, improvement, or replacement of either the executive or BODY model.

The BODY model provides continuous, real-time cardiovascular, respiratory, and pharmacological simulation based on a 6 millisecond timing interval. A variety of physiological data, including the electrocardiogram (ECG) and arterial pressure waveform, are available as continuous, sampled data streams and may be viewed as if the patient was connected to a physiological monitor (Figures 2 & 3). Other variables, such as heart rate (HR) and respiratory rate (RR), are available as discrete data and may be viewed by numeric (Figures 2, 3, & 4) or trend display (Figure 4).

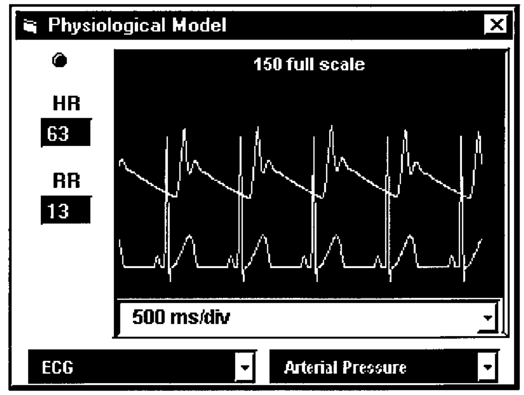

Figure 4. Physiological monitor showing ECG and arterial pressure waveforms.

BODY was converted from a DOS-based program to a Windows Dynamic Linked Library (dll) and extended for trauma patient simulation. Critical trauma-related incidents may be set to occur at the beginning or later in the simulation, with a specific probability of occurrence.

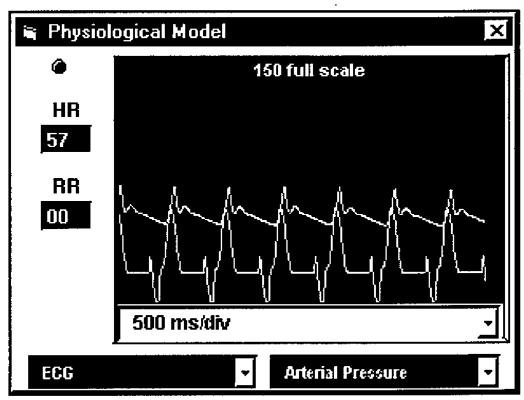

Figure 5. ECG and arterial pressure waveforms after a period of exsanguination.

The following trauma-related incidents are supported:

Administer pain stimulus
Set airway obstruction
Set bleeding rate and duration
Set myocardial contractility index
Set cardiac tamponade blood leak rate and pericardial volume limit
Set pneumothorax severity and type
(simple, tension, open, hemo)
Set leg amputation severity and level
(foot, knee, thigh)

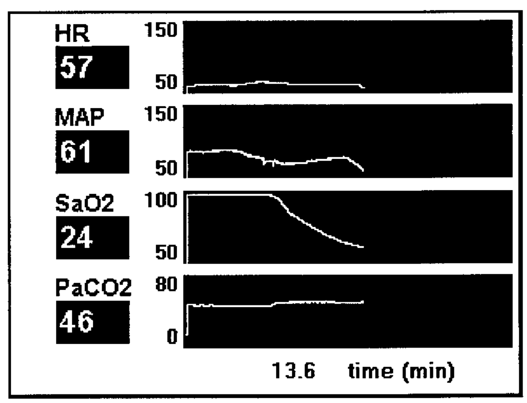

Figure 6. Heart rate, mean arterial pressure, oxygen content, and arterial CO2 trend data before and after diazepam overdose.

A complete list of BODY Simulation™ model functions and data is provided in Appendix B.
A list of BODY drug models selected by the COTR for VMET-TPS is provided in Appendix C, column 1.
Readily-available drug models that may be added to VMET-TPS are provided in Appendix C, column 2.

3.3 Visual modeling

The majority of the caregiver-patient interaction takes place in the VR window, which comprises the scene, the casualty, and medical materiel. Each of these elements was optimized to maintain acceptable system performance with the bulk of the polygon budget being allotted to the casualty.

3.3.1 Human model

The 3-D human visual model comprises approximately 12,000 polygons, judiciously reduced from a 52,774 polygon model of the nude human male acquired from Viewpoint Data Labs (Orem, UT). The reduced model was segmented into 96 body parts (e.g., chest, upper, left), and each body part associated with one or more texture maps (i.e., regional skin surface image) for visual rendering. During VR rendering, the set of body parts is "reassembled" to provide a complete visual rendition of the nude human male.

A variety of body animations was developed to provide feedback in trauma patient assessment and to heighten the simulation experience. Five models each of the right and left hands and toes were developed to animate finger and toe wiggling for motor assessment in the detailed physical exam (secondary survey). Five models each of the right and left pupils were developed to span the range from fully constricted to fully dilated. Both the initial size and pupillary response may be set upon injury to reflect neurological damage. Eye closure was also animated to support both blinking and closure. Blinking occurs spontaneously, depending upon level of consciousness, and with a randomly-varying blink interval. As a patient loses consciousness, the eye closure duty cycle increases to the point of complete closure.

Each 3-D body part is a "clickable" VR object and may be associated with a specific set of caregiver interactions in performing patient assessment, conducting treatments, or other procedures. Some actions are regional, so that clicking on any part of the head (for example) would produce a response irrespective of the specific point selected on the head. These regional parts are called "parents" and their subparts called "children."

To conserve video memory, all uninjured body parts were assigned a uniform texture map (skin tone). Injured body parts were produced by assigning injury-specific texture maps (based on wound photographs provided by the Army) to copies of the uninjured 3-D body-part model. The 2-D wound images could not be used directly because of certain 3-D modeling issues. However, the images provided a reference for artistic rendering of the wound to the 3-D model. Example wounds are presented in Figure 5, and a list of injury models is provided in Appendix D.

The nude male model was augmented with 3-D clothing and cultural models (shirt, pants, boots, helmet, and gear). Because many 3-D graphics display adapters have limited z-buffering (16 layers), layering thin objects spaced closely together (e.g., clothes or bandages over skin) does not always present an appropriate visual display. To address the z-buffering problem, we developed software to either overlay or substitute the clothing and cultural objects for the associated body region and to manage clothing removal.

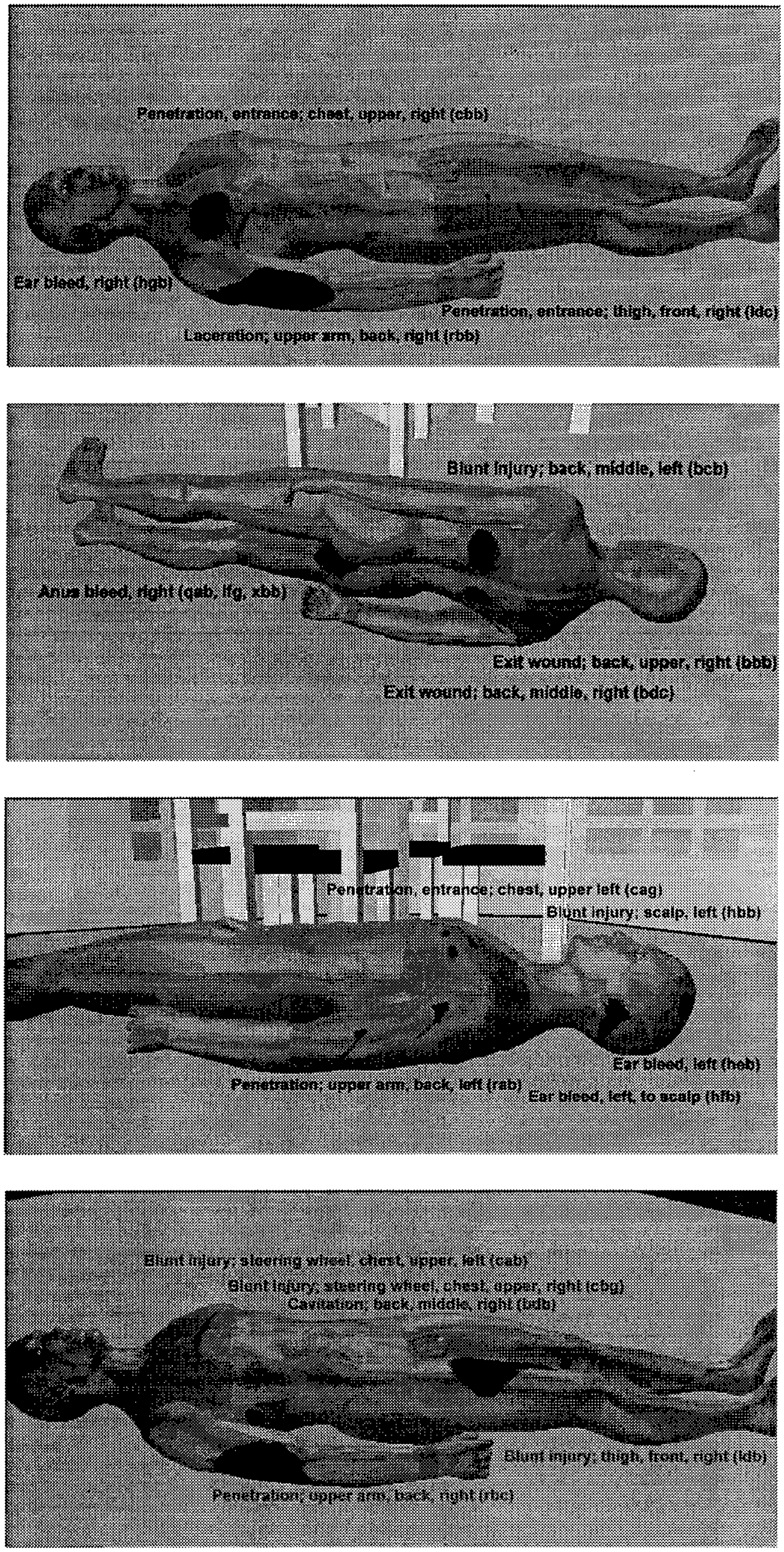

Figure 7. Human male model with examples of visible injuries.

3.3.2 Advanced human model

During model development, limitations in the Viewpoint Data Labs source model were identified that made it difficult to implement animations of natural human movement (e.g., abducting the arms; smooth chest movement with unbroken skin in synchrony with respiration). Furthermore, the basic model appeared somewhat unnatural without gradations in skin tone, body hair, apparent musculature, and other visual attributes. We therefore began development of a new model to support these dynamic characteristics and visual attributes based on a model source called Poser (MetaCreations, Carpinteria, CA).

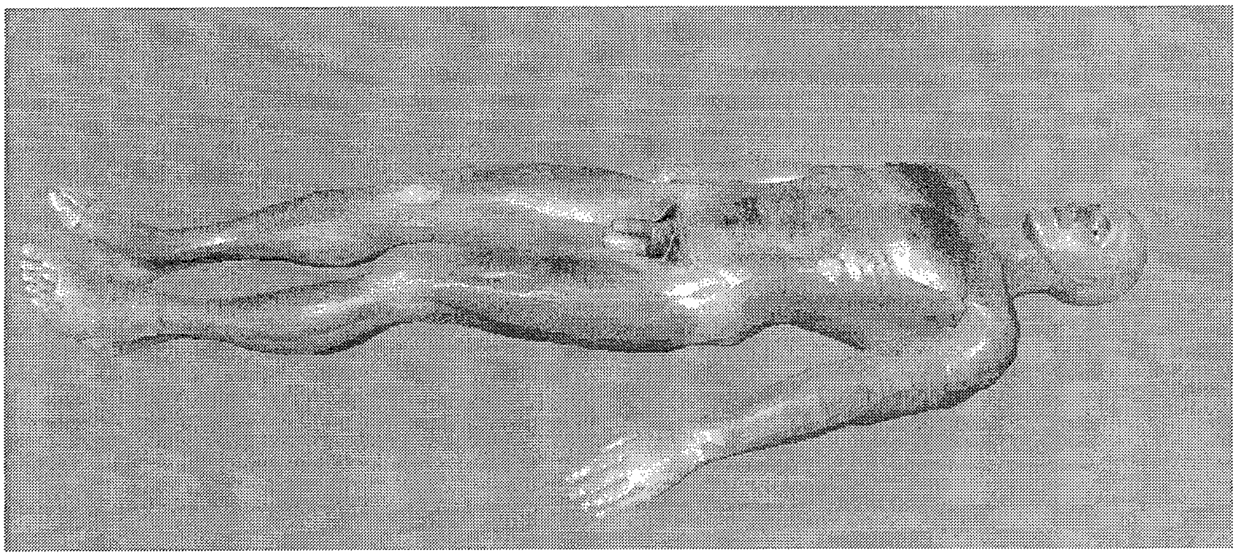

Figure 8. Advanced human male model with full-body texture map.

As in the basic model, the Poser-based model was segmented into body parts and each body part was associated with a surface texture for visual rendering. However, the Poser source model came with a full-body texture map which gave it a significantly improved visual appearance (Figure 6). Following segmentation, the advanced model was reassembled and augmented using Character Studio to add internal "muscles" and "tendons" for character animation. Character Studio facilitates human-like animation with automatic morphing of skin surfaces during movement. An animation of respiratory chest movement was generated in the graphics development environment and videos of shallow and heavy breathing were produced as a test visualization.

At this point in the advanced model development, limitations in 3-D file conversion from the graphics development environment to the DirectX 3-D rendering engine used in VMET-TPS were identified that precluded the use of this new animation methodology. To implement automatic morphing of skin surfaces in DirectX 3-D, custom software will have to be developed. This development was outside the aims and well beyond the scope of the project, consequently further advanced model development was not pursued. Although the fully-textured model exhibited a substantial performance penalty on the VMET-TPS simulation, the problems should be short-lived as better animation support appears and graphics performance improves.

3.3.3 Scene and medical materiel models

To engage the user in an immersive experience, the casualty model is placed within a 3-D scene that provides not only a backdrop for the medical simulation, but also elements of scene safety, mechanism of injury, and environmental conditions. The object-oriented and component-based VMET architecture permits reuse of injured body models in different scenes and reuse of scenes with different injured body models. This flexibility, coupled with variable scene attributes of weather, time-of-day, disturbances, and sounds provides a wide variety of simulation experience.

To develop and test multiple scenarios, four 3-D scenes were developed: a European village, a kitchen, a mountain highway with overlook, and a field aid station. The mountain highway scene was then extended with a car/bus crash as a disturbance. The polygon count for these scenes ranges from several hundred to over a thousand, in addition to the 12,000 polygons for the body.

The VMET-TPS provides a suite of tools and procedures to support patient assessment and medical care that are grouped as airways and ventilation, bandages and dressings, chest trauma management, drugs and fluids, equipment, immobilization devices, instruments, and vascular access. Many of these tools and procedures employ medical devices and materiel that appear as 3-D objects in the scene. Each tool that is displayed adds 10-30 polygons to the overall scene.

3.4 Aural modeling and caregiver-patient dialog

The VMET-TPS employs multiple audio features to further engage the user in the simulation. Environmental and ambient sounds add realism (both orientation and distraction) to a visual scene. Available sounds include jungle birds, office noise, traffic, surf, battle, helicopter, rain, and thunder. To help establish mechanism of injury, several brief event sounds are available, including gun fire, car crash, falling, and an explosion. For patient assessment, a representative set of body sounds is available, including heart, lung, and diminished lung sounds. Limited trauma-related sounds (e.g., sucking chest wounds) constrained use of this feature.

Scene and body sounds are played and mixed as requested or scheduled using DirectX sound technology. Body sounds are evoked either by placing the ear to the mouth (to check breathing) or by employing the stethoscope tool. Presently these are no spontaneous body sounds.

Caregiver-patient dialog is based on RTI's proprietary integrated VR and spoken human-machine dialog component software (Guinn and Montoya, 1997). This software incorporates COTS speech recognition and RTI natural language processing capabilities with the following features (Figure 7):

- Speaker-independent speech recognition (IBM ViaVoice engine)
- Error-correcting parsers that can correctly handle utterances that are outside the grammar
- Dynamic natural language grammars that change as the situation context changes
- Spoken message interpretation that can resolve pronoun usage and incomplete sentences
- Spoken message reliability processing that computes the likelihood of understanding (This score can then be used to ask for repeats or confirmations.)
- Goal-driven dialog behavior so that the computer is directing the conversation to satisfy either the user-defined or computer-defined objectives

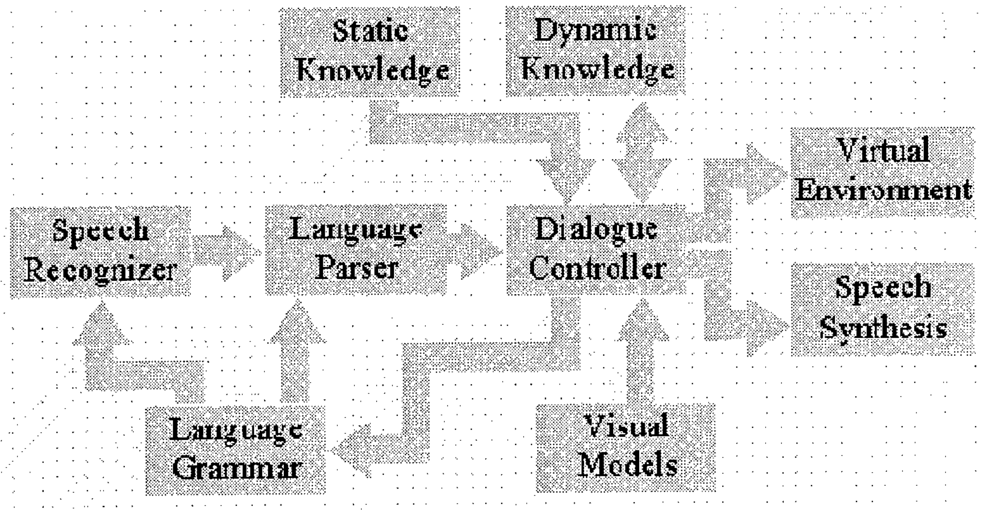

Figure 9. VMET-TPS Natural Language Processing architecture.

For VMET-TPS, this technology was extended to caregiver and patient behaviors consistent with expected casualty care dialog and patient responses in the field. These behaviors include:

- Caregiver-initiated dialog based on specific patient assessment needs
- Patient responses specific to, scenario, mechanism-of-injury, and medical history
- Patient speech and vocalizations based on current level-of-consciousness

A set of 46 caregiver questions was devised to initiate a dialog based on specific patient assessment needs. To assess level of consciousness, for example, the caregiver may ask "Do you know what day it is?" Assuming that the patient (i.e., computer) understood the question, then the patient would respond appropriately (e.g., "No," or "I think it's Tuesday"). If the patient's consciousness is impaired, he/she may respond incorrectly, inappropriately, or not at all. As the level of consciousness diminishes, the patient responds more and more inappropriately, progressing to moaning, babble, and silence.

The caregiver questions may be initiated by list selection or by speech recognition. Speech recognition requires a second audio adapter. The patient's responses are available via three mechanisms: a pop-up text box, computer-generated text-to-speech, and pre-recorded audio files (Windows wave format).

For each patient in each scenario, a mapping of possible responses to each caregiver question must be defined. Furthermore, as new scenes and mechanisms of injury are added to the library, additional responses must be defined and recorded. For this project, a set of 40 responses was devised for a casualty who had received a gun shot wound. That casualty was then placed in three scenes, thus producing three scenarios. At present, the caregiver-patient dialog feature can be demonstrated only in these three scenarios.

3.5 Medical care modeling

VMET-TPS takes the user through the sequence of trauma-patient assessment, beginning with entering and sizing up the scene, determining level of consciousness, checking the ABCDs, and attending to major life-threatening conditions. A selected set of lifesaving medical procedures, medical devices, and pharmacological agents is available to address immediate patient needs.

Available medical procedures are defined and organized in an hierarchical, relational database of protocols, tasks, and actions. Each protocol (e.g., Initial Assessment) comprises a list of tasks (e.g., Assess Circulation), and each task comprises a list of one or more actions (Figure 10).

Actions are made up of one or two parts, the "method" for performing the action (e.g., check pulse) and (optionally) a body object (i.e., graphical hot spot) that is selected (e.g., neck, carotid areas) to carry out the action. Actions that are not directly related to a body hot spot simply contain the user method.

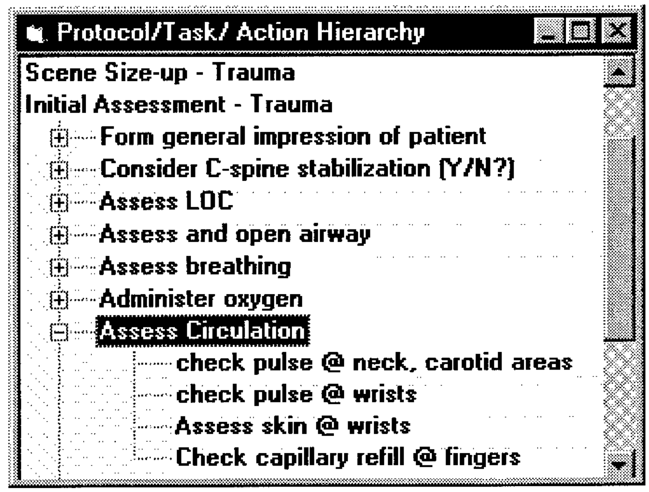

Figure 10. Example of protocol, task, action hierarchy for the initial assessment of trauma protocol

Methods may be related to a specific tool or device, either to carry out the method or to appear in the 3-D scene as a result of a patient interaction. For example, a "stethoscope" tool must be selected to listen to lung sounds, but a stethoscope does not appear. However, selecting a cervical collar from the tools menu and "placing" it on the patient's neck causes a 3-D collar to appear in the scene.

Interactive menus, voice, and hot spots are used to execute patient care methods. Menus are used to execute methods that do not require direct interaction with the patient or other elements in a scene. For example, when selected from a tool menu, the method "Place long spine board" causes a long spine board to appear in the scene beneath the patient. Voice input (or a voice menu) is used to execute methods that require the patient to hear a command (e.g., "Wiggle your fingers.") or answer a question, (e.g., "Are you OK?").

Hot spots are used two ways to execute methods related to a particular body object. For example, when the user selects "check pulse" from the Touch methods list, then clicks on the "wrist" using the left mouse button, the CHECK_PULSE software module will obtain the systolic and diastolic blood pressure from BODY, translate those values to a qualitative statement of the patient's pulse at the wrist (e.g., "weak and thready pulse"), and report it in a message box. The user may also click on the "wrist" using the right mouse button and evoke "check pulse" from the wrist's hot-spot related methods list. Lack of quantitative definitions for patient states (e.g., thready pulse, cyanosis, pallor) made these definitions somewhat arbitrary.

The VMET-TPS executive model responds to emergency care interventions (e.g., perform head-tilt to open airway) by first determining if the intervention was effective (some procedures have

an assignable probability of success that is less than unity). If the intervention is held to be effective, the VMET-TPS executive model sets appropriate BODY simulation parameters to induce physiological responses, makes necessary changes to the 3-D visual representation, (optionally) presents a video or slide show of an actual procedure, and affirms completion of the action to the caregiver via a text message. Unavailability of video clips for medical procedures (e.g., chest tube insertion) constrained the number of procedures that could be presented.

Seven protocols, 256 tasks, 465 actions, 166 methods, and 75 tools are defined in the VMET-TPS database. The principle benefit of the hierarchical, relational database is that within the bounds of an existing set of implemented methods, the protocol, task, action, method, and tool relationships can be altered without rewriting VMET software. This means that the same software can support multiple levels of medical expertise (i.e., Emergency medical technician (EMT), medic, nurse, physician) or multiple medical protocol jurisdictions (i.e., Army, Navy, Durham County, Commonwealth of Virginia) by simply modifying the database. Furthermore, although new methods may require additional software and 3-D models, any new methods are easily integrated into the database.

3.6 System operation

VMET-TPS integrates the simulation, medical, and administrative database content, dynamic configuration of the 3-D body model, 3-D medical material models, other simulation resources, the user interface, and courseware into an interactive learning environment.

3.6.1 User interface

The user interface has a general layout comprising three small windows for presenting options lists and multimedia data (TOP), a mode and tool-selection tool bar (MIDDLE), and an interactive virtual reality display of the casualty scene (BOTTOM).

In the example screen (Figure 11), the VR window presents a casualty who has sustained gunshot wounds to the chest and the right arm. The blood pool beneath his back hints of a significant exit wound. Using the "scissors" tool from the "Tools" list selection, the caregiver has already removed the shirt and military gear from the soldier. Likewise a variety of medical care has been provided: applying a cervical collar, applying a bag-valve-mask, applying a 3-sided dressing to the chest, performing a pericardiocentisis, and bag-valve-mask ventilation. The multimedia windows present the following (left to right):

1. a video representing the "capillary refill test" after selection from the "touch" menu list;
2. a dynamic list of available actions performed via "Touch" for selection by the caregiver; and
3. a two-channel waveform display of physiological data from the BODY model (electrocardiogram and central arterial pressure).

Figure 11. An example screen showing TPS multimedia and VR displays.

During operation of the TPS , the multimedia windows are dynamic, changing content and display layout according to data presentation, interactive care-giving, and software administrative requirements of the moment. Additional "pop-up" displays also appear, overlaying the VR screen and multimedia windows, for brief presentation of casualty-related data (e.g., pulse rate upon wrist hot-spot interrogation), selection of secondary options (e.g., method for manual airway opening), step-wise protocol-task-action mentoring, and error messages.

Direct casualty interactions employ anatomical "hot spots" (e.g., neck, left) related to specific protocol actions (i.e., check pulse, inspect for bleeding) to simulate "hands-on" patient care in the virtual environment. Secondary casualty interactions employ either menu-driven (e.g., log roll to left side, back, and right side) or hot-spot related (e.g., apply cervical collar) methods to achieve desired results. In the VMET-TPS, right-clicking on a body location presents a pop-up a list of location-related actions. Some actions, e.g., palpating for bleeding, require you to point the crosshair cursor on the 3-D simulated patient and click the left mouse button. Other actions, such as taking a pulse, further require that the place pointed to is the anatomically-correct area (e.g., the wrist).

3.6.2 Interacting with the program

The VMET-TPS uses straightforward mouse-based, keyboard-based, voice-based, and menu-based manipulations to use the simulator effectively.

Program entry, scenario selection, and patient selection are all performed by choosing the appropriate item from the buttons or menus presented and typing the requested information (student name, password, etc.). At the beginning of a simulation, a scenario description is displayed to provide background information on the nature of the ensuing simulation,

Once the simulation begins, the caregiver can survey and navigate about the VR scene from its initial entry point by using the left and right mouse buttons:

- Depressing the left mouse button and moving the cursor left and right causes translation of the viewpoint left and right, respectively
- Depressing the left mouse button and moving the cursor up and down causes the viewpoint to move forward and back, respectively
- Pan and tilt are similarly controlled by depressing the right mouse button and moving the cursor left/right or up/down, respectively. (Note that the cursor changes from a crosshair to a four-ended arrow when its function changes from a selection or pointing device to a navigation indicator.)
- Function keys F1 and F2 can be used to zoom in or zoom out (with either left or right mouse button held down and moved slightly to activate the navigation mode)

Furthermore, a menu of fixed viewpoints can be selected from the "View" button on the toolbar. These manipulations provide the elements of navigation and immersion essential for VR.

The cursor may be moved to a body part and right-clicked to produce a menu of options related to that body part. Left-clicking the menu item causes a pop-up information text box to appear, a video clip of a procedure to be shown, or a 3-D object to appear in the VR window.

The caregiver can "converse" with the patient by selecting the "Talk" button from the tool bar. If speech input has been enabled, then the system will accept a spoken statement from the caregiver. If the speech input is not enabled, then the caregiver may select a query or command from a menu of phrases.

The caregiver's statement will be analyzed by the speech recognizer, matched to the list of likely queries or commands, and a response that is consistent with the patient's consciousness level will be produced. The patient's responses come from recorded files, from the text-to-speech synthesizer, or are presented in a text box. When recorded speech from the patient is not available, the text response is sent to the text-to-speech converter to produce an audible response.

During free simulation, the caregiver continues to interact with the patient as needed until the patient expires of his/her injuries, the caregiver releases the patient, the caregiver transfers the patient to the next echelon of care, or the caregiver exits the program. Upon exit, a complete list of caregiver-patient interactions is available for review.

3.6.3 Training modes

VMET-TPS provides three training modes: learning, mentoring, and simulation. In the learning mode, the student selects a patient assessment protocol (e.g., Rapid Trauma Assessment) prior to interacting with the casualty. The software will then present a series of actions and action-collections in lock-step with the (pre-defined) selected protocol. As the actions are performed, they are scored and recorded, the student is advised whether the action was correct or incorrect, and the states of the casualty's physiology and virtual environment are changed appropriately. In the mentoring mode, the student is expected to execute the actions in correct order from memory. Again, the system responds to his or her actions accordingly. In the simulation mode, free-play interaction with the casualty is encouraged, while all student-system interactions are recorded for subsequent analysis and review. This mode provides an accurate simulation of actual medical care without the interruption of intrusive training or mentoring information.

3.6.4 On-line tutorial and context-sensitive help

To facilitate using the patient assessment simulator, RTI developed an on-line tutorial using hypertext markup language (HTML) and related it to the run-time environment using context-sensitive help. The tutorial provides both a step-by-step introduction into operation and a reference guide for the experienced user. Throughout the interactive user interface, "HELP" buttons are available to display tutorial and reference information related to the currently active topic.

The use of HTML for these functions, rather than the standard Windows Help resource, has multiple benefits. First, the tutorial and reference code is easily maintained at low cost. Elements of the reference document may be ported to the World Wide Web. Sources of related technical information that exist or become available on the World Wide Web (e.g., other web-based simulators, anatomical references) may be incorporated into the documentation with minimal effort. Finally, as related courseware becomes available at AMEDD C&S, such materials could be converted to HTML and linked directly to the system within the appropriate context for student reference.

3.7 Demonstrations and feedback

A very early version of the TPS was demonstrated at the Global Forum on Telemedicine conference (Tyson's Corner, March 1997). Personnel from the MRMC, the Uniformed Services University of the Health Sciences, Naval Medical Corp, and other military and civilian organizations viewed and commented on the system. The general acceptance was very good. Most observers expressed training benefits that could be gained in their domain by providing medical experience through patient assessment and trauma care simulation.

The PI and COTR were observers at the Combat Trauma Life Support course held at the Uniformed Services University of the Health Sciences (Bethesda, June 1997). The TPS was shown to several attendees, including experienced combat medics, physician assistants, and physicians. The general acceptance was very good with several expressing their desire to use TPS for sustainment training.

Over 50 military and civilian emergency medical service (EMS) providers from the US and abroad (mostly NATO) viewed and tried the VMET-TPS at the Association of Military Surgeons of the United States* (AMSUS) (Nashville, November 1997). Many expressed their interest in using VMET-TPS, and more than 30 individuals submitted a statement of their specific training requirements and potential use of VMET-TPS in their facility or practice.

At the Interservice/Industry Training, Simulation, and Education Conference* (I/ITSEC) (Orlando, December 1997), VMET-TPS was shown to a variety of medical training personnel including representatives from the Army, Navy, Air Force, and Coast Guard. Again, acceptance was very good with several expressing their desire to use the system when completed.

VMET-TPS was presented at the Medicine Meets Virtual Reality 6 (MMVR) symposium (San Diego, January 1998) (Kizakevich, et al, 1998) and demonstrated at the Advanced Simulation Corporation exposition booth. We used this opportunity to further interact with AdvSim on the physiological modeling task, meet with the COR, and to receive feedback on TPS from others attending the conference. The feedback was excellent, resulting in inquiries from a range of emergency medicine educators, including some from Mexico, Brazil, Italy, and Hong Kong.

Also in January, Ty Smith and AdvSim presented interim work on the revised BODY models at the 1998 Joint Meeting of Society of Technology in Anesthesia & Rochester Simulator Meeting* (N. Ty Smith, et al, 1998). A brief demonstration of the VMET-TPS was given within their talk.

VMET-TPS was later demonstrated at the 16th Annual EMS Today Conference and Exposition* (Baltimore, March, 1998). Most of the attendees were senior, civilian EMS providers including paramedics, EMTs, training instructors, and department officials. The system was well received with about 20 individuals requesting access to the system for EMT, physician, and nurse training.

At the 44th Medical Brigade Senior Leader Conference* (Fayetteville, April 1998), VMET-TPS was shown made to a group of medical personnel from Fort Bragg and other regional military bases. The reception was positive, with several participants offering to "test" the software in their training center.

The last demonstration was at the 4th Annual Brooke Army Medical Center Trauma Symposium (San Antonio, July 1998). An invited talk was presented to the nursing track of the symposium and hands-on demonstrations were provided in the exhibit hall. About 40 persons tried the systems. About 10 expressed interest in using the system for sustainment training.

The first TPS system was delivered, installed, and demonstrated to the at the Army Institute for Surgical Research, Brooke Army Medical Center, in May of 1998. A second system was delivered on July 10 to the same location, and a brief training session was held with the COTR and one of the medic trainers.

Note: Demonstrations at conferences marked with an asterisk (*) were conducted off project.

3.8 Discussion

The original ACT II topic (97-LAM-04) sought a Trauma Patient Simulator, suitable for training medics, physician assistants, and physicians, that would represent:

- the physiological dynamics of combat casualties (including cardiovascular, pulmonary, gross central nervous, and renal systems), especially responses to trauma, ischemia, and shock
- the physiological responses to emergency medical intervention, including the pharmacokinetics of blood, resuscitative fluids, and drugs
- interaction with anticipated military medical technology
- coordination with constructive tactical engagement simulations.

In collaboration with the COR, the COTR, and their representatives, we focused our efforts on and have shown examples of how each of the first two requirements above may be met. The VMET-TPS demonstrated in this contract has addressed each of these topics. We used a combination of 3-D, virtual reality, multimedia, and human-machine dialog to produce a simulator with both visual variety and physiological accuracy that runs on an affordable PC platform with COTS software and hardware.

To the extent that conventional trauma-care devices represent "anticipated military medical technology," we have addressed that topic as well. As new concepts in military trauma-care become available (e.g., life support for trauma and transport (LSTAT), telesurgery), the VMET-TPS architecture can incorporate visual and physiologically-functional models of devices and protocols, facilitate their evaluation via simulation, and support their introduction via training.

Achievement of the project goals for the target system required several tradeoffs among system performance, situation realism, and system cost. For example, video clips have been used to illustrate procedures such as capillary refill assessment of peripheral circulation, and pop-up text has been used to describe procedures such as thoracentesis. The underlying premise that justifies such substitution is that the intention of the simulator is to teach good cognitive or decision-making skills, and that manikins, part-task trainers, and moulaged actors are more appropriate for teaching hands-on or tactile skills.

In addition to the stated requirements, we have also provided a wide range of capabilities in the simulator, such as administrative functions for record-keeping and reporting, modularity to accommodate changes in protocols and physiological engines, tutorial information, and capabilities for accessing related information on the Web.

4.0 CONCLUSIONS

We have demonstrated that the relatively mature technologies of personal computers, COTS software, and readily-available COTS hardware can be used to create a trauma patient simulator that is suitable for training medical personnel. These technologies were used to further develop an extendable, component-based architecture for a family of trainers that will be more comprehensive, accurate, and engaging as the available technologies and our understanding of the physiology of trauma continue to advance.

We also developed the structure and samples of content for libraries of scenes, bodies, body parts, wounds, internal injuries, medical materiel and devices, and medical procedures and interventions. Further development of these libraries and associated physiological models might be coordinated with existing and future physiology of trauma projects to gather data for improved patient simulators. These data would not only improve the simulation, but also would facilitate the transfer of new treatment methodologies to the practicing medical personnel.

From a development perspective, we can conclude that the project objective and specific aims were largely met and, in some cases, exceeded. From a scientific perspective, we can conclude little since a formal test of the efficacy of VR-based training in combat casualty care was outside the scope of work. A necessary next step should be a well-controlled study that compares outcomes of conventional training and VR-based training.

We have only the anecdotal evidence of interest, based on several hundred civilian and military medical personnel witnessing TPS demonstrations during its development, some of whom also operated the simulator. These included medics, medical corpsmen, nurses, EMTs, paramedics, physician assistants, physicians, and training managers. Many were interested in TPS as a personal tool, while others were interested in TPS to meet institutional or program training needs. Although training is usually thought of as initial acquisition of knowledge and skills, the primary interest was for sustainment and recertification. Suggestions for other VMET-based systems included nursing care, dentistry, ventinary care, medical examination, and field-hospital setup.

Clearly, the enthusiasm voiced by the medical community for the Trauma Patient Simulator indicates that VR-based training fills a need in trauma-care education, because we were most frequently asked, "When will this be available for MY training program?"

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APPENDICES

APPENDIX A

Project Personnel

Research Triangle Institute

Paul N. Kizakevich	Principal Investigator
Michael L. McCartney	Co-Investigator, Physiology Simulation
Ingrid B. Agolia	Technical Administration
John W. Holloway	VR Graphics
Pamela J. Woodward	VR Graphics
Maria W. Ashbaugh	VR Graphics
James Wright	Computer Support
Susan K. Grantlin	Education Specialist
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Daniel B. Nissman	Software and Medical Analysis
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Dean H. Herring	Graphics Management
Robert F. Helms	Virtual Reality Projects Coordination
Dale W. Rowe	Research Management
John G. Pless, Jr.	Audio and Video
Cliff O. Haac	Video

Graphics Media Systems (Subcontractor)

Steve Milligan	VR Graphics

Advanced Simulation Corporation (Subcontractor)

Ken Starko	Physiology Simulation Software
Chris Haddock	Physiology Simulation Software
N. Ty Smith	Physiology Simulation Consultant

APPENDIX B

BODY Simulation™ Functions and Data Interface

The BODY Simulation™ model provides continuous, real-time cardiovascular, respiratory, and pharmacological simulation via Windows Dynamic Linked Library (dll). The following functions and data are supported:

Administrative functions:

MODELDISPATCHER - execute one simulation interval (clock tick)
Set BODY database directory

Input interface functions and data

Place mask on patient
Remove mask
Intubate
Extubate
Adjust intubation tube
Set tube depth
Squeeze respiration bag
Inject drug (specified drug and location)

Anesthesia machine control calls

Set fresh gas flow
Set O_2 percentage
Set tidal volume
Set respiratory rate
Set positive end expired pressure
Set inspired to expired ratio
Select inhaled agent
Set the agent flow in % of total flow
Sets pressure relief valve

Trauma-related incidents

Administer pain stimulus
Set bleeding rate and duration
Set airway obstruction
Set myocardial contractility index
Set cardiac tamponade blood flow and pericardial volume limit
Set pneumothorax type (simple, tension, open, hemo) and severity
Set leg amputation location (foot, knee, thigh) and severity

Cardiovascular output variables

EKG waveform
Arterial pressure waveform
Central venous pressure waveform
Pulmonary arterial pressure waveform
Heart rate
Arterial systolic pressure
Arterial diastolic pressure
Mean arterial pressure
Pulmonary arterial pressure
Pulmonary arterial diastolic pressure
Mean pulmonary arterial pressure
Hemoglobin Saturation
Estimated myocardium O_2 deficit
Blood flow in muscle compartment (peripheral blood flow)

Respiratory output variables

Airway CO_2 and O_2 partial pressure waveform
Airway pressure waveform
Respiratory rate
End tidal volume
End tidal CO_2
Arterial O2 partial pressure
Arterial CO2 partial pressure
Tracheal air flow
Right & Left bronchus air flow
Total lung volume

Neurological output variables

Estimated brain O_2 deficit
Eye position (indicates consciousness, paralysis, and blinking)
Depth of anesthesia
Degree of neuromuscular block

APPENDIX C

Drugs Supported by Physiological Model

VMET-TPS Drugs	Available VMET Drugs
atropine	adenosine
curare	alfentanyl
diazepam	aminophylline
dobutamine	atracurium
dopamine	bretylium
epinephrine	calcium chloride
etomidate	digoxin
isoproterenol	diltiazam
ketamine	droperidol
lidocaine	edrophonium
midazolam	ephedrine
morphine	esmolol
naloxone	fentanyl
norepinephrine	flumazenil
phenylephrine	glycopyrrolate
sodium bicarbonate	labetalol
succinylcholine	meperidine
vecuronium	methadone
	methohexital
	metocurine
	metoprolol
	mivacurium
	neostigmine
	nifedipine
	nitroglycerine
	pancuronium
	phentolamine
	pipecuronium
	procainamide
	propofol
	propranolol
	rocuronium
	sodium nitroprusside
	sufentanil
	thiopental
	verapamil

APPENDIX D

Scenario Worksheet Instructions

A scenario comprises a scene (i.e., environment) in which some incident has occurred and caused trauma to one or more bodies. In the current version of VMET-TPS (June 1998) only one body will be included per scene.

SCENE DEFINITION

Information describing the scene (i.e., environment) in which the trauma event has occurred.

Scene Title:	for selection list, do not give away patient information
Learning Objective:	brief statement for instructors
Concept Author:	your name
Concept Date:	date
Opening Statement: (viewed by student)	this is the statement presented to the student upon entering the scene
Scene:	village kitchen aid_station highway (select)
Incident: (consistent with wounds)	statement of what happened (e.g.. Automobile/bus crash)
Mechanism of Injury 1:	(e.g., blunt steering-wheel injury to chest)
Mechanism of Injury 2:	
Mechanism of Injury 3:	

BODY DEFINITION

Information describing the injured body at the onset of the simulation.
A body without hemorrhage (e.g., head wound) may be assigned a fixed LOC status. LOC is also dynamically affected by blood loss (actually mean arterial pressure).

Body Title:	body identifier not shown to student (e.g., blunt injury to head; penetrating leg wounds)
Initial LOC:	alert verbal pain unconscious (select)
Initial Eye score:	no_response pain verbal spontaneous (select)
Initial Motor score:	no_response extension flexion(ab) flexion(normal) obeys_command (select)
Initial Verbal score:	no_response sounds words disoriented/converses orient/converses (select)

INJURY DEFINITIONS

Injury attributes assigned to the body. Refer to the attached color images (Figures 1-6) for injuries examples. For each injury, complete the following injury attributes specification.

Visible injury: (if marking any, mark only one)	**Wound and body location**	**Code**	**Figure**		
	Exit wound, back, upper, right, GSW1	bbb	6		
	Exit wound, back, middle, right, GSW2	bdc	6		
	Cavitation, back, middle, right (armpit), GSW3	bdb	1		
	Contusion; back, middle, left, bruise1	bcb	6		
	Contusion; steering wheel, chest, upper, left, bruise2	cab	1		
	Contusion; steering wheel, chest, upper, right, bruise3	cbg	1		
	Contusion; scalp, left, bruise4	hbb	3		
	Contusion; thigh, front, right, bruise5	ldb	1		
	Penetration, entrance, chest, upper, left, shrapnel1	cag	3		
	Penetration, entrance, chest, upper, right, GSW4	cbb	2		
	Penetration, thigh, front, right, GSW5	ldc	2		
	Penetration, upper arm, back, left, GSW7	rab	3		
	Penetration, upper arm, back, right, GSW8	rbc	1		
	Laceration, upper arm, back, right	rbb	2		
Bleeding:	XXX ml/min	arterial	venous	(enter rate and select source)	
Bleeding quality:	none	minimal	moderate	severe	(select one)
Tenderness:	none	minimal	moderate	severe	(select one)
Instability:	none	minimal	moderate	severe	(select one)
Crepitus:	none	minimal	moderate	severe	(select one)
Distention:	none	minimal	moderate	severe	(select one)
Rigidity:	none	minimal	moderate	severe	(select one)
Comment:					

INJURY SIGNS

Secondary injury attribute. Complete as above.

Visible injury: (if marking any, mark only one)	**Wound and body location**	**Code**	**Figure**		
	Nosebleed1	hkb	4		
	Nosebleed3; to face, right	hcb	4		
	Nosebleed4; to face, left	hdb	4		
	Earbleed1; ear, left, to back	heb	3		
	Earbleed2; ear, right, to back	hgb	2		
	Earbleed3; ear, left, to scalp, left	hfb	3		
	Anus bleed1; rectum	qab	5,6		
	Anus bleed2; thigh, back, left	leb	5		
	Anus bleed3; thigh back, right	lfg	6		
	Anus bleed4; buttock, left	xab	5		
	Anus bleed5; buttock, right	xbb	6		
Bleeding:	ml/min	arterial	venous	(enter rate and select source)	
Bleeding quality:	none	minimal	moderate	severe	(select one)

BODY SCRIPTS

The body script is checked once per second for programmed changes in the simulation. To set an initial condition, set the script time to 00:00. The probability for all events may be forced to 100% during the simulation via a VMET-TPS program option setting.

You may mark more than one script process if all probabilities are equal.

Time (min:sec)							
Script process:	**Sign, calamity, event, etc.**		**Parameter options**				
(if marking any,	**Apnea**		yes	no			
mark only one)	**Airway obstruction**		minimal	moderate	severe		
	Simple Pneumothorax		minimal	moderate	severe		
	Tension Pneumothorax		minimal	moderate	severe		
	Open Pneumothorax		minimal	moderate	severe		
	Hemothorax		minimal	moderate	severe		
	Cardiac tamponade		minimal	moderate	severe		
	Blood pooling, external		minimal	moderate	severe		
	Eye blink (both)	yes	no				
	L pupil size = [ ]	mm		**R pupil size =** [ ]		mm	
	L pupil light response	yes	no	**R pupil light response**		yes	no
	L hand perf. deficit	yes	no	**R hand perf. deficit**		yes	no
	L hand motor deficit	yes	no	**R hand motor deficit**		yes	no
	L hand sensory deficit	yes	no	**R hand sensory deficit**		yes	no
	L leg perfusion deficit	yes	no	**R leg perfusion deficit**		yes	no
	L leg motor deficit	yes	no	**R leg motor deficit**		yes	no
	L leg sensory deficit	yes	no	**R leg sensory deficit**		yes	no
	Skin color	flush	blanch	cyanotic			
	Skin	dry	clammy	fever			
	Priapism	yes	no				
Probability (%):							
Comment:							